Yield, Quality, Water Use, and Weeds in Annual Forage-Spring Durum Cropping Systems

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History & Development

Strategic planning workshops were conducted in 1996 in Montana, Nebraska, and North Dakota with the purpose of identifying and providing solutions to agricultural production concerns, pest management problems, and economic issues for dryland wheat production in the Northern Great Plains and Mountain farm production regions. Numerous research needs were identified by participants at these workshops including: cropping systems management, fertility responses, appropriate non-cereal rotation crops, pest management options for rotation crops, marketing strategies for rotation crops, economic benefits of non-cereal rotations, etc. Participating producers also requested that university and extension faculty investigate diversified cropping systems and determine the long-term economic and environmental impacts of these systems.

The "Sustainable Pest Management in Dryland Wheat" research and demonstration project was designed to evaluate crop diversification in the dryland wheat ecosystem. The project has the following specific objectives:

Objectives

Objective 1: Evaluate pests and pest management using selected cropping sequences and tillage systems on large experimental blocks representing different farming regions in Montana.

Objective 2: Investigate the interaction of crop rotation and tillage systems with

- physical and biological properties of soil
- weed species composition
- presence and absence of plant pathogens
- beneficial and pest insects

Objective 3: Determine the economic profitability, marketing, and environmental benefits of diversified cropping systems.

Three study sites were selected for this project.

Site 1 (Mark Peterson Grain and Cattle, Inc.) is located in north central Montana approximately 50 km north of the MSU Northern Agricultural Research Center – Havre and is a 23 ha parcel in the Conservation Reserve Program for 10 years prior to the initiation of this experiment.

Site 2 (Tyler Ranch) is located in central Montana, 16 km east of the MSU Central Agricultural Research Center – Moccasin, and is a 16 ha block that has been in small grain production for several decades.

Site 3 is located in northeast Montana near Froid. This site is owned by the Sheridan and Roosevelt County Conservation Districts and is approximately 72 km north of Sidney, Montana.

Study sites differ climatologically and agronomically from one another yet each represents a significant production area within the state.

This poster presents results from the Froid location.

Materials & Methods

Site History. The Froid site consists of 18 acres on the Roosevelt and Sheridan County Conservation District farm, 7 miles south of Froid, Montana. Plots are located on a Williams loam soil (fine-loamy, mixed Typic Argiboroll). Average annual precipitation is 360 mm, with about 290 occurring during April through September. The site was uniformly cropped to durum in 1999, lentil for green manure in 2000, and durum in 2001.

Crop Rotations. Four rotations with durum are included in this trial, along with continuous alfalfa. Specific rotations include:

1. Summer fallow - durum
2. Barley (hay) - durum
3. Pea + barley (hay) – durum
4. Foxtail millet (hay) - durum
5. Continuous alfalfa

The experimental design is a randomized complete block. Each crop rotation sequence is present in each of three replicates. Individual plot size is 21 x 61 m.

Crop Management. Fertilizer nitrogen requirements for durum wheat were based on a common yield goal of 2350 kg ha^{-1}, subtracting out nitrate-nitrogen present in the 0-60 cm soil zone from the required 118 kg ha^{-1} nitrogen requirement. Annual hay crops received recommended nitrogen fertilizer rates based on soil tests. All annual crops also received annually preplant applications of 56 and 45 kg ha-1 of 11-52-0 and 0-0-60, respectively. Fertilizer blends were applied with a Valmar prior to disking for preplant tillage. Seed were planted with a drill equipped with double-disk openers on 20 cm spacing. Planting dates of durum and cool-season forages were in the third of April each year, while foxtail millet, a warm-season species intolerant of frost, was seeded in late May 2002 and 2003, or early June 2004.

Weed management is an important component of this study. Annual forage crops do not receive any herbicide application. Durum plots were treated with bromoxynil, MCPA, and fenoxaprop in 2002 and 2004, but in-crop herbicides were not applied in 2003. Weeds were identified and quantified in 10 0.1 m^2 quadrats prior to crop canopy closure. Weeds were identified, quantified, and harvested from 2 0.5 m^2 rectangular quadrats per plot shortly before grain or hay harvests. Grain yields were determined by harvest with a plot combine equipped with a 1.5 m header. Soil water values were determined with gravimetric sampling in 6 increments to 1.5 m depth, followed by conversion to volumetric water concentration with bulk densities. Water use from each 0-1.5 m profile was calculated as:

rainfall + preplant soilwater – postharvest soilwater.

Initial **analysis** of each parameter was done over years with PC-SAS. When effects of Year, or Interactions with Year were significant, analysis of variance was done using General Linear Models for a randomized complete block design. Means separations, when F Tests were significant, were done with the Least Squares Means procedure at P=0.05.

Froid Site: The experimental plots are located in the middle of this picture.

Results

Rainfall. Precipitation during April through September has been relatively normal for 2001 through 2004, ranging from 260 to 295 mm, with the long-term average for this site at about 290 mm.

Crop yields and quality. The effects of Year and interaction of Year X Rotation were significant for numerous parameters, so results are presented within years. Durum yields (100% DM) have been substantially above our yield goal of 2350 kg ha^{-1}, ranging from 2490 to over 4200 kg ha^{-1} (Table 1). Durum grain protein varied among rotations in 2003, with durum following fallow having the highest concentration. Protein concentrations did not vary among rotations in 2004. Crop aboveground biomass trended similarly to grain yield, with no differences among rotations in 2003, while in 2004 durum in rotation with fallow accumulated more biomass than durum following annual hay crops. Averaged across the three annual forages, durum following annual forages averaged a 24% loss of yield over two years, about 730 kg ha^{-1} year^{-1}, compared to durum following summerfallow.

Durum and soil water. Pre-plant and post-harvest soil water to 1.5 m, and crop water use by durum did not vary significantly among rotations in either year (Table 2). Water use efficiency for durum grain production varied among rotations in 2004, with durum following fallow have a higher WUE than durum following annual forage crops.

Annual hay crops varied significantly for aboveground crop, weed, and total biomass (Table 3). Crop biomass of foxtail millet was lower than other entries, except for alfalfa in the establishment year, 2002. Sole crop barley and barley with pea yielded similarly each year. Total weed biomass was always greatest with foxtail millet. Weed biomass in the barley and pea+barley crops has been negligible despite the absence of in-crop herbicide applications. Total biomass, crop and weeds combined, trended differently among years. Alfalfa yielded the lowest forage in 2002, the year of establishment. However, alfalfa had the highest yields in subsequent years. Although the replacement of summerfallow with annual forages resulted in the average loss of 730 kg ha^{-1}. Actual baled forage yields were substantially lower than total aboveground biomass for most crops (Table 3). Alfalfa and cool-season annual forages barley and pea+barley have received substantial rainfall during crop curing. Additionally, several windstorms carried away swathed forages prior to baling in 2002 and 2003.

Water use by forages varied among crops in 2003 and 2004, but not in 2002 (Table 4). Established alfalfa used the most water, likely due to its ability to root deeper than any of the annual crops included in this trial. Crop WUE was lowest for alfalfa in the year of establishment. The WUE of total biomass varied in 2002 and 2003, but not in 2004. Alfalfa had the lowest biomass in 2002 and consequently had the poorest WUE that year, while the annual forages had remarkably similar WUE.

Successful management of weeds in alternative cropping systems is a key component to their adoption by growers. The most common weed species encountered in these plots include green foxtail (*Setaria viridis*), kochia (*Kochia scoparia*), Russian thistle (*Salsola iberica*), horseweed (*Conyza canadensis*), wild buckwheat (*Polygonum convolvulus*), and barnyardgrass (*Echinochloa crus-galli*), with green foxtail (SETVI) being the most predominant weed. Early season SETVI densities differed among forage crops, but trends were not consistent across years (Table 5). However, at forage crop harvest, SETVI density did not vary among forage crops. Conversely, SETVI biomass did vary significantly among forage crops each year, with foxtail millet having the highest SETVI biomass at harvest. The April planting dates used for the cool-season forages has allowed them to outcompete the later emerging SETVI. Foxtail millet, closely related to SETVI, is by necessity seeded after the last expected spring frost. Emergence of this millet and SETVI can be highly coincident, putting the crop under intense competition with the weed, particularly for water. Seed production by SETVI has never been observed in either of the cool-season annual forages, barley and pea+barley, but has occurred in foxtail millet. Forage quality of SETVI and foxtail millet were quite similar at the same phenological stage of development (data not presented).

Early season and preharvest SETVI densities in durum did not vary by the previous year's annual forage crop or fallow in 2003. However, in 2004 durum following foxtail millet had more SETVI postemergence and preharvest than durum following other forages or fallow (Table 6), despite the application of fenoxaprop. Durum in 2003 was not treated with any in-crop herbicide for broadleaf or grass weed control, yet SETVI biomass was very low, probably due to early planting of durum and excellent early growth. In 2004, despite early planting of durum, SETVI densities were quite high in durum in all rotations, particularly durum following foxtail millet, and treatment with fenoxaprop was required to prevent crop yield loss. The application of fenoxaprop did not prevent additional flushes of SETVI from occurring, and densities were still high at harvest, but as seen from the very low biomass values (Table 6), competition from SETVI was likely insubstantial.

Tables

Table 1. Stands, grain yield and protein, and biomass of durum grown in four crop rotations, Froid, Montana, 2003-2004.

Year and Crop Rotation	Crop Stand	Grain Yield	Grain Protein	Crop Biomass
	# m^{-2}	kg ha^{-1}	mg kg^{-1}	kg ha^{-1}
2003				
Fallow – **durum**	170	3204	159 a	5923
Barley – **durum**	150	3150	132 b	5027
Pea+barley – **durum**	162	3133	141 ab	5170
Millet – **durum**	162	3200	127 b	4932
2004				
Fallow – **durum**	200	4225 a	119	10005 a
Barley – **durum**	195	2779 b	124	6624 b
Pea+barley – **durum**	203	3157 b	130	6925 b
Millet – **durum**	166	2490 b	127	5829 b

Means within columns and year followed by different letters differ significantly at P=0.05.

Table 2. Preplant and postharvest plant available soil water (PAW), water use, and water use efficiency of durum in four crop rotations, Froid, Montana, 2003-2004.

Year and Crop Rotation	PAW-preplant	PAW-postharvest	Water Use	WUE-grain
	mm	mm	mm	kg mm^{-1}
2003				
Fallow – **durum**	185	124	224	14.3
Barley – **durum**	175	109	226	13.9
Pea+barley – **durum**	178	99	239	13.1
Millet – **durum**	188	117	231	13.9
2004				
Fallow – **durum**	193	134	312	13.5 a
Barley – **durum**	186	141	298	9.4 b
Pea+barley – **durum**	182	118	316	10.0 b
Millet – **durum**	171	122	302	8.3 b

Means within columns and year followed by different letters differ significantly at P=0.05.

Table 3. Crop, weed, and total biomass, and bale yield from alfalfa and three annual forage crops in rotation with durum, Froid Montana, 2002-2004.

Year and Crop Rotation	Crop Biomass	Weed Biomass	Total Biomass	Bale Yield
	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
2002				
Barley – durum	4295 a	35 c	4329 a	2337 a
Pea+barley – durum	3767 ab	159 c	4309 a	1826 a
Millet – durum	2993 b	1314 a	4307 a	2843 a
Alfalfa	1176 c	768 b	1944 b	628 b
2003				
Barley – durum	5020 b	68 b	5088 c	1736 c
Pea+barley – durum	5361 b	83 b	5443 b	1739 c
Millet – durum	3349 c	2305 a	5655 b	2676 b
Alfalfa	6319 a	47 b	6366 a	3307 a
2004				
Barley – durum	5953 a	187 b	6140 a	4641 a
Pea+barley – durum	5389 a	108 b	5498 ab	5022 a
Millet – durum	2748 b	1518 a	4266 b	3301 b
Alfalfa	6316 a	147 b	6463 a	3264 b

Table 4. Preplant and postharvest plant available soil water (PAW), water use, and water use efficiencies for alfalfa and three annual forage crops in rotation with durum, Froid Montana, 2002-2004.

Year and Crop Rotation	PAW preplant	PAW postharvest	Water Use	WUE crop biomass	WUE total biomass
	mm	mm	mm	kg mm^{-1}	kg mm^{-1}
2002					
Barley – durum	135	119	165	26.0 a	26.2 a
Pea+barley – durum	132	117	165	22.8 a	26.1 a
Millet – durum	124	127	165	18.1 b	26.1 a
Alfalfa	142	140	173	6.8 c	11.2 b
2003					
Barley – durum	198	119	236 b	21.5	21.8 b
Pea+barley – durum	178	127	208 c	25.9	26.3 a
Millet – durum	168	140	196 c	17.5	29.2 a
Alfalfa	201	107	343 a	18.5	18.5 b
2004					
Barley – durum	163	146	219 ab	27.3 a	28.1
Pea+barley – durum	178	130	249 a	22.1 ab	22.5
Millet – durum	184	155	180 b	15.2 b	23.6
Alfalfa	152	85	254 a	25.3 a	25.9

Table 5. Early season and preharvest green foxtail density and green foxtail (SETVI) biomass in alfalfa and three annual hay crops in rotation with durum, Froid, Montana, 2003-2004.

Year and Crop Rotation	Early season SETVI	Preharvest SETVI	Preharvest SETVI
	# m^{-2}	# m^{-2}	g m^{-2}
2002			
Barley – durum	33 b	172	3 c
Pea+barley – durum	79 b	379	15 c
Millet – durum	255 b	326	124 a
Alfalfa	623 a	254	70 b
2003			
Barley – durum	372 ab	595	6 b
Pea+barley – durum	511 a	780	7 b
Millet – durum	251 bc	548	228 a
Alfalfa	102 c	790	2 b
2004			
Barley – durum	814	872	8 b
Pea+barley – durum	886	826	6 b
Millet – durum	76	274	134 a
Alfalfa	260	522	1 b

Table 6. Early season and preharvest green foxtail (SETVI) density, and green foxtail biomass in durum in rotation with three annual hay crops and fallow, Froid, Montana, 2003-2004.

Year and Crop Rotation	Early season SETVI	Preharvest SETVI	Preharvest SETVI
	# m^{-2}	# m^{-2}	g m^{-2}
2003			
Fallow – **durum**	111	158	31
Barley – **durum**	74	102	15
Pea+barley – **durum**	84	102	18
Millet - **durum**	195	158	18
2004			
Fallow – **durum**	752 b	74 b	1
Barley – **durum**	1043 b	185 b	3
Pea+barley – **durum**	843 b	99 b	2
Millet - **durum**	4316 a	1084 a	4

Conclusions

We have completed three years of alfalfa and annual hay crop production in rotation with spring durum, and have collected two years of data on durum production following summerfallow and annual hay crops that did not receive in-crop herbicides. All three years have had reasonably normal precipitation annually and during the growing season. Although we intend to conduct this study for additional years, we are able to make some conclusions.

- Diversified, intensified rotations with annual forages replacing summer fallow can increase overall rotational productivity, but even if rainfall is normal, durum grain yield losses do occur compared to durum following fallow.
- Annual forages replacing summerfallow have reduced water use compared to durum.
- Some annual forages produced without in-crop herbicides do not increase weed densities in the subsequent crop. This practice, however, requires additional research at other locations with different predominant weed communities.

By decreasing herbicide use and efficiently utilizing water, annual forage crops should be a substantial improvement compared to fallow for environmentally sustainable crop production in the Northern Plains.

Economic analyses of these rotations are required to determine economic sustainability.